International Journal of Finance and Commerce
www.commercejournals.com
Online ISSN: 2664-715X, Print ISSN: 2664-7141
Received: 21-01-2023, Accepted: 04-02-2023, Published: 23-02-2023
Volume 5, Issue 1, 2023, Page No. 55-59

Financial engineering utilizing mathematical techniques, solving financial problems

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Abstract
Financial engineering is the lifeblood of financial innovation. It is the process that seeks to adapt current financial products and processes to the emerging requirements of financial market players and other participants. It has completely changed the financial market today. The engineering of finance process uses tools and knowledge from the fields of economics, statistics, applied mathematics and computer science. It is the application of scientific principles to the art of investment.

Keywords: financial engineer, financial engineering, financial problem, man-finance system, mathematical techniques

Introduction

Financial engineering is not finance and engineering, nor is it the finance of engineering. It is engineering of finance. Engineering can be defined as design and operation of man-machine systems. Then, financial engineering may be defined as design and operation of man-finance system.

The man-finance system involves not merely finance aspects, but its interface with man. For example, financial products have to deal with the individual risk profile of human beings. Further, just as in man-machine systems, machine is a contrived sub-system, in man-finance systems, finance is a contrived sub-system.

Financial engineering like any other engineering has brought several new products and solutions to the market. It has completely changed the financial market today. Its main contribution is to split the risk and return into several components and allow investors of financial markets to decide the combination that is most suitable to them. Such innovations are seen in bonds, equity, derivatives, and also in other fields like merger, acquisition and corporate restructuring. It also provides mechanism to price such combinations by developing various pricing models for futures and options. Some of the models are cost-of-carry model, binominal model, Black-Scholes Option Pricing Model, etc. Today, it is possible to quantify risk and return of any new products and also price them with the help of these models. Financial engineering is an exciting field, which attracts some of the best human resources. The profession is also highly rewarding.

Financial Engineering: A Neo- Discipline

Financial engineering may be defined as the design and redesign of financial instruments like derivatives and other products to structure cash flows to achieve the desired financial goals, which inter alia, includes improvement of return and/ or risk characteristics in tune with the changing environment of market, taxation, legal or general economy. It is the lifeblood of financial innovation. It is the process that seeks to adapt current financial products and processes to the emerging requirements of financial market players and other participants.

Financial engineering involves utilization of mathematical techniques in solving financial problems. This process uses tools and knowledge from the fields of economics, statistics, applied mathematics and computer science. These tools not only assist in solving the prevailing financial issues but also help in devising innovative financial products. Financial engineering is also known as quantitative analysis. Investment banks, commercial banks and insurance agencies use this technique.

The term financial engineering together can be explained as the process of using engineering tools and techniques of mathematics, statistics, computer science to solve the financial problems of the organizations, investors, government etc. It helps in simplifying the activities related to investment or we can say it is the application of scientific principles to the art of investment.

The process of financial engineering

Financial engineering process is no different from the process that any firm follows in developing new value added products or services. The process starts with identification or realization of some needs. Sometime such needs are known but many times, you have to identify the needs of the market and bring out products or services or solution to the users without expecting them to formally communicate such needs. Like car manufacturers, mutual funds managers have to constantly look for ways to innovate new products that are appealing to investors and at the same time achieve certain additional objectives. It is quite possible that you may add one more feature to the existing products, which increase its value to users. For example, an open-end fund gives liquidity compared to close-end funds but still investors have to fulfil so many formalities to get the money. Cheque book facility to mutual funds holder takes away so many formalities relating to redemption and provides instance liquidity.

Corporate finance managers have to look for ways to reduce cost of capital or reduce the risk arising out of operating activities. Treasury managers of banks while talking to clients can get ideas for new product or solutions. Once the need is identified, an initial sketch of the product is developed. At this stage, depending on the product requirement, complex model building exercise is used. For instance, a structured derivative product requires high level of mathematical modelling. The next stage is testing of the

product so check whether the desired result is achieved. Sometime it involves simple verification with the users or some senior managers' assessment. Sometime, you may have to run some simulation exercise to verify how the product will produce results under various simulated future scenario. Once the product is perfected, the next stage is pricing of the product. At the stage of pricing, it is quite possible that the price paid by the customer may be more than the benefit derived out of the product. So, the product may be restructured again so as to make it attractive to the users. Finally, the product is launched or solutions are provided either directly or after some test marketing.

Evolutionary phases of financial engineering

It strict sense, it may not be factual to say that financial engineering is only of recent origin. This came into existence when money in the form of currency and coins was contrived though many may not recognise it as financial engineering. But it certainly qualifies to be labelled as such since it eminently fits into aforementioned description of financial engineering essentially as man-finance system. Thus, the oldest and the most basic financial engineering system can be depicted systemically as shown in figure 1 where in the barter system of trading in goods and services was replaced by the concept of money, a financial product being a derivative of value proposition of goods and services. This financial engineering system may be labelled as the first order financial engineering system and money as the first order derivative of commodities, goods and services.

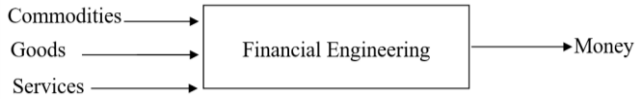

Fig 1: First Order Financial Engineering System

The next evolutionary step in the development of financial engineering system was emergence of equity and debt instruments as derivatives of cash and its varied options of payments. This led to the development of organised financial markets. The financial engineering system that made this possible is labelled here as the second order financial engineering system and the associated financial instruments are second order derivatives of commodities, goods and services as depicted in figure 2. Once again it is to be recognised that this framework also is in tune with earlier understanding of financial engineering system.

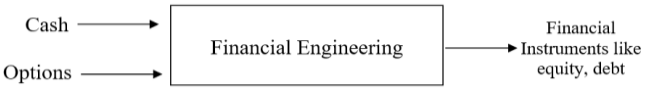

Fig 2: Second order financial engineering system

The next and the recent most evolution in financial engineering is the way financial engineering is understood and the term 'financial engineering' itself is coined and came to be accepted as a new discipline.

It is like any other physical process with input comprising primary securities like debt, equities etc. output comprising derivatives of different kinds like forwards, futures, swaps and options, and the transformation process is financial engineering as illustrated in figure 3. Again it is a man-finance system; herein named as the third order financial engineering system and the associated derivatives are the third order derivatives of commodities, good and services. This development made a profound impact on business through depending and broadening of financial markets.

The foregoing three orders of financial engineering systems may be thought of as a hierarchy of financial engineering systems with increasing order of system complexity.

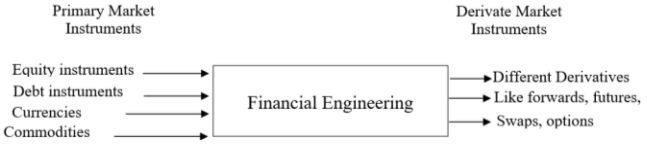

Fig 3: third order financial engineering system

The third order financial engineering, now known and practiced as a new discipline 'Financial Engineering', is a multi-disciplinary and inter-disciplinary subject. As a multi-disciplinary subject, it involves the areas of finance, economics, business, computational tools and quantitative techniques. As an inter-disciplinary subject, it represents convergence of the five disciplines leading to the emergence of a new discipline of study. This is illustrated in figure 4.

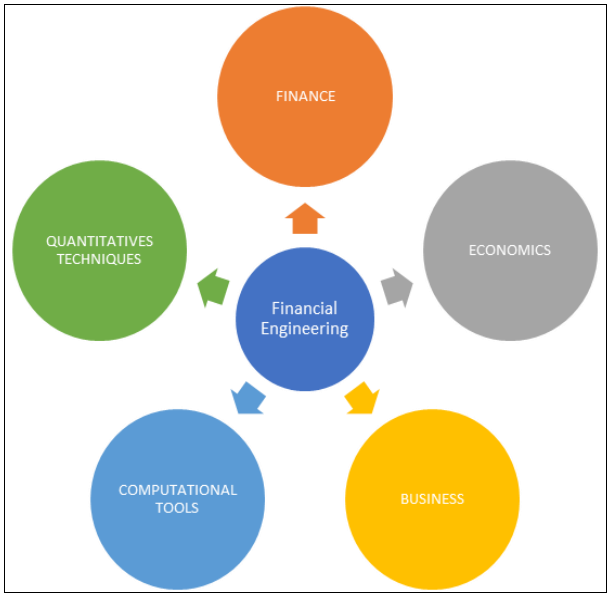

Fig 4: Multi-and Inter-disciplinary Character of Financial Engineering

Now onwards, third order financial engineering is referred to merely as financial engineering. Using mathematical modelling and computer engineering, financial engineerings are able to test and issue new tools such as new methods of investment analysis, new debt offerings, new investments, new trading strategies, new financial models etc.

Factors influencing financial engineering

The following are the factors that influence the growth process of financial engineering:

Environmental Factors

These are the factors which exist in the external environment. Environmental factors have a direct impact on the firm. These factors are not controllable.

Political, Economic, Social and Technological (PEST) analysis can be conducted to determine these factors and their impact on the business. Common examples of environmental factors are

1. Price volatility

With the advent of globalization, there has been increase in the volatility in the financial market. A slight change in the global market can send waves in the national market. The recent example of this fact was the Global Recession of 2008 where the recession in the global market sent shock waves to financial markets of various countries. The demand and supply forces determine the price in the market. Higher volatility increases risk and thus the need of Financial engineering also increases as these financial engineers helps in finding ways to deal with these volatilities. The volatility also increases the investment opportunities and the experts can exploit these opportunities in their favour and earn huge profits.

2. Globalization

Globalization has opened up the market globally. The investors' base has increased and with the help of automated computer systems, this has become even more popular. Now the investors can trade in international market also but this has also increased the exposure towards risk. This increase in the volume of trade and investment has increased the demand of financial engineers.

3. Tax Asymmetries

The difference in the tax structure of different countries can be exploited by the financial engineers as they are experts in this field. Tax Asymmetries exist for number of reasons:

- Granting special tax exemption to some industries.
- Existence of different tax burdens in different countries and even different tax law for domestic and foreign firms doing business within a country.
- Nature of past performances has left some firms with sizable tax credits and write offs which effectively eliminate any tax obligations for some years to come.

4. Technological advances

Improvement in computer technology along with advances in telecommunication led to high speed data transmission. Synergy of these technologies with software programming led to advent of spreadsheet programs. With the introduction of spreadsheet programs currency and interest rate swap blossomed. Technological advances have motivated a great deal of financial engineering. Many of technological breakthroughs involve the computer, high speed processors, powerful desktop units, network systems, and enhanced methods of data entry, and so on.

5. Development of new markets and market linkages

There has been an explosive growth of futures and options exchanges worldwide. 24 hour trading has become possible on futures and options exchanges across the globe. The Chicago exchange has developed a computer system on which trade can now be carried out at any time, replacing human activity on the floor. Now, the same trend is being seen around the world. India is no exception.

6. Regulatory change and increased competition

Increased competitive pressures, better risk management techniques, coupled with the 1980's atmosphere of deregulation led to the growth of financial engineering.

7. Transaction and information cost

Enormous technological development decreased the cost of information, on which many transactions feed. Thus, the cost of transacting itself declined significantly during the decade of 1980's. Unlike today under 1970's transaction cost, arbitrage opportunity does not exist.

Intra Firm Factors

These factors are controllable by the firm and directly affect the financial engineering process. Examples of intra firm factors are

1. Balance between liquidity and profitability

The need to maintain liquidity is a driving force behind financial engineering. The liquidity and profitability do not go hand in hand. If an investor wants liquidity, it will have to play safe and make only those investments in which he is sure of reasonable returns but the profitability will decline. In order to improve profitability, the investor will have to invest in aggressive securities and thus the liquidity declines. The financial engineer can easily manage the balance between liquidity and profitability by innovating new products which can balance the both.

2. Risk aversion

A rational investor will always want to avoid the risk. The risk cannot be eliminated completely but can be limited by making careful choice of investments. The investors will be ready to bear the risk only if they are compensated for bearing the risk. There are various financial products in the financial market that can balance the risk exposure of the investors. Financial engineers help them in making such decisions.

3. Agency costs

Financial engineering also helps reducing agency costs by innovating various strategies to deal with the issues related to ownership and control. The conflict of ownership and control is difficult to sort but financial engineers are experts and they may generate new methods to seek these issues.

4. Technical knowledge of investment managers

Sound technical knowledge of the financial managers can help the growth of the financial engineering in the economy. They can also provide training to investment professionals to deal with the situations.

Tools Required for Financial Engineering

It is the knowledge of the financial engineer that can help the investors from financial crisis. The financial engineers use various financial products and services for the benefit of economy at large. In relation to tools requirement of financial engineering process, basically, two types of tools are used named

- Conceptual Tools and
- Physical Tools.

Conceptual Tools

This category involves the combination of concepts and ideas that can be used in finance studies and are considered as formal disciplines. Mostly these types of tools are taught in business programs especially at graduation level. For instance, hedging theory, valuation of theory and its application, portfolio theory, risk and return measurement, accounting relationships, and tax treatment under different forms of business organization, understanding interest rates and exchange rates, speculation, arbitrage and market efficiency etc.

Physical Tools

Special process and instruments that are used by Financial Engineers in combination to gain a specific task or purpose are called as physical tools. The examples include variants, securities, futures, swaps, options, and equities.

At a very broad level, the basic instruments are cash market instruments and derivatives. Cash market instruments including debt market instruments like fixed income securities, and equity and equity related securities. Derivatives include, forward contracts, future contracts, swaps and options. Derivatives instruments are an outcome of financial engineering. To appreciate the contribution of financial engineering by quantifying risk, allocating risk and managing the risk through derivatives under which the currencies, futures, options, swaps and commodities are traded on the exchanges.

Pivot Role of the Financial Engineer

The persons who apply these techniques are known as financial engineers. The financial engineers are different from financial analysts. The financial analysts only analyses the information available for the Risk management whereas Financial engineers find out innovative ways, products, instruments, models to either eliminate or reduce or optimise the risk. For example: If an individual-investors wants to reduce risk or improve profitability they can approach these engineers who can create portfolio in such a way that investors get satisfied. The financial engineers not only manage the risk but also help in formulating strategies, new financial products, instruments for the firms, government, households, individuals etc. to maximise their wealth in this competitive business. Financial engineers create, design and implement new financial models and processes in order to find solutions for problems. They always seek new financial opportunities. Preparing such models requires a great deal of research and they rely on in-depth data analysis, simulations, risk analysis and stochastic.

What a financial engineer does is similar to what an electrical engineer does with electricity and its flow. The financial engineer uses mathematical models to track the flow of money through world markets. He identifies a need and tries to fulfil it in an innovative way, through coming out with an engineered product with existing securities as its elements.

Hence, role and functions of the Financial Engineer is being described hereunder:

- The financial engineers are specialists making use of mathematical formulas, programming and engineering methods in financial theories, and analyses market trends to build data backed financial models.
- Companies often employ people with advanced degree in Financial Engineering and these specialists work as investment managers, bankers or traders using their financial engineering background to improve the quality of existing investment products. An investment product is a product (such as stocks, options, futures, bonds, mutual funds, certificates of deposit, money market investments, ETFs and annuities) purchased with the expectation of earning a favourable return.
- This knowledge is used by engineers to develop simulations and predict market behaviour. Of course, the predictions aren't always accurate, any unexpected issue may happen in the financial market but the risk potential reduces. Since a financial engineer knows about market trends and previous market performances, the knowledge is used to make future investment predictions.
- Apart from knowledge in finance, the engineer needs to possess sufficient computer programming skills. Programming skills are needed to build simulating financial models to learn about market behaviour. Through these simulations, the financial engineer is expected to generate results, as much as accurately possible.
- Most of the financial engineers work in the field of financial risk management and as financial analyst. With the knowledge of computer simulations and market trends, the engineer helps to develop profitable investment plans for individuals and companies. Often these investment plans have high risk factor, which might seem counter-productive to the goal of hiring financial engineers, but that's a strategy used by risk management firms to yield higher return than comparatively stable investments. Companies and high net-worth individuals often take help from financial engineers to design a portfolio which places the complete investment capital at risk.
- As a financial analyst, the financial engineer creates real time financial simulations to predict the future behaviour of the market.

Conclusion

Financial Engineering has been in existence right from the day when monetary system replaced barter system of trading transactions. From then onwards, Financial Engineering evolved into a new discipline drawing from diverse disciplines. The emergence of modern Financial Engineering facilitated development of financial markets and enhanced their efficiency and effectiveness.

The derivatives- forwards, futures, swaps and options, and their innumerable variants have helped business to craft and carry out a risk-management strategy that is most appropriate to their risk-seeking capability and behaviour.

Finally, we may opine that financial engineering can benefit organizations in finding solutions to various problems such as risk management, scenario simulation and new product development. However owing to the ever-increasing financial innovation, there is a perpetual demand for highly skilled financial engineers.

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